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6. AUTHOR(S)
J. Drummond, E. Cheng, and W. Gex

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RDT&E Division
San Diego, CA 92152–5001

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VOICE AND VIDEO TRANSMISSION USING XTP AND FDDI

John Drummond
Naval Command, Control and Ocean Surveillance Center RDT&E Division (NRaD)
San Diego, CA 92152-5000

Edwin Cheng
Naval Command, Control and Ocean Surveillance Center RDT&E Division (NRaD)
San Diego, CA 92152-5000

Will Gex
Naval Command, Control and Ocean Surveillance Center RDT&E Division (NRaD)
San Diego, CA 92152-5000

ABSTRACT

The use of XTP and FDDI provides a high speed and high performance network solution to multimedia transmission that requires high bandwidth. FDDI is an ANSI and ISO standard for a MAC and Physical layer protocol that provides a signaling rate of 100 Mbits/sec and fault tolerance. XTP is a Transport and Network layer protocol designed for high performance and efficiency and is the heart of the SAFENET Lightweight Suite for systems that require high performance or realtime communications. Our testbed consists of several commercially available Intel based i486 PCs containing off-the-shelf FDDI cards, audio analog-digital converter cards, video interface cards, and XTP software. Unicast, multicast, and duplex audio transmission experiments have been performed using XTP and FDDI. We are working on unicast and multicast video transmission. Several potential commercial applications are described.

INTRODUCTION

Multimedia (voice, video, data, text, and graphics) distribution over high speed networks has many commercial applications which will revolutionize the way we use computers and networks. Several big corporations have already formed strategic alliances to explore new opportunities in this area.

We have been researching and experimenting for several years with high speed networks which utilize Fiber Distributed Data Interface (FDDI), and a high performance network protocol called Xpress Transfer Protocol (XTP). As multimedia increased in popularity, in both military and commercial world, we started to look at the possibility of using XTP and FDDI in voice and video transmission. We have performed many voice transmission experiments using XTP with several PC i486 machines connected via FDDI network. The results indicate voice transmission using XTP and FDDI have many advantages over traditional methods of voice transmission such as fault tolerance, high bandwidth, and data integration. Right now, we are performing video transmission experiments using XTP and FDDI.

XTP

The Xpress Transfer Protocol (XTP)[1] has been developed over the past seven years from a consortium of private industry, academia, and government to address many high performance and realtime issues that were lacking in previously developed transport and network protocols. Certain concepts from existing protocols (e.g.VMTP, GAM-T-103, Delta-t, NETBLT) were modified and combined with new ideas to form the basis for XTP. Experience and other ideas have added to its development to produce the current specification[2].

It is a protocol that spans the Network and Transport layers (layers 3 and 4) of the OSI 7 layer model and therefore has some interesting features due to the coupling of an end-to-end protocol with an intermediate, network protocol (e.g. bandwidth reservation of an intermediate resource by an end host or packet priority assigned by an end host and used by an intermediate router). Because the protocol does not specify policy but

supplies many mechanisms, it is very flexible and allows an application to determine the needed policy (e.g. reliability or best effort, connection or datagram, multicast or unicast). This flexibility allows applications to communicate efficiently without undue overhead from unneeded mechanisms or policies.

Some of the features of XTP that address efficiency are:

- Multicasting with some end-to-end reliability
- Rate control
- Selective retransmission
- Application control of acknowledgments
- Implicit connection setup with data
- Flexible error control (reliable or best effort)
- Flexible flow control (variable window or no flow control)
- Optional data checksum in a trailer (vice header)
- Connection ID exchange
- Header and trailer field alignment on 4 byte boundaries

XTP supports realtime systems in three areas by offering:

- Flexible communication paradigms
- Flexible degrees of reliability
- Message discrimination for scheduling

In the voice and video applications developed at NRaD, some of these mechanisms were used to increase the efficiency of the communications. The largest efficiency gain came from the use of multicast which allowed the source host to transmit a single voice or video packet over the network to a group of receivers. As this group of receivers grew, little additional overhead was required of the transmitter to distribute the voice or video to the larger group.

FDDI

The Fiber Distributed Data Interface (FDDI) is an American National Standards Institute (ANSI) standard based on token ring technology. Basically, it is a network of nodes connected by two fiber cables with a logical token circulating among the nodes and a signaling rate of 100 Mbits/sec. The FDDI architecture is fault tolerant and the network will remain operational if a single fault, such as a cable break, occurs. The FDDI features that are useful in the transmission of voice and video are:

- High bandwidth (100 Mbit/sec)
- Very low error rates (10^{-9} BER)
- Predictable token access (low jitter)
- Large packet size (4500 bytes)

Other features that are useful for Military purposes are:

- Fault tolerance
- No electromagnetic emissions
- No electromagnetic interference
- Notion of priority

EXPERIMENTS

Our testbed consists of several commercially available Intel based i486 PCs containing off-the-shelf components. Each network node PC is populated with Dual Attached Station (DAS) FDDI cards developed by Network Peripherals Inc. (model NP-EISA/2), 10-bit resolution audio analog-digital converter cards using Adaptive Differential Pulse Code Modulation (ADPCM) audio compression with 16 kHz sample rate developed by Antex Electronics (model VP 625), and 2-card set of video interface boards consisting of Visionary VIS-1A Joint Photographic Experts Group (JPEG) video compression hardware and Visionary VIS-2A frame grabber engine which perform the digital video capturing and compression functions (developed by Rapid Technology Corp). All PCs are connected by a dual ring fiber optic cable. The software consists of DOS 5.0 (developed by Microsoft), drivers for each of the hardware items mentioned above (developed by their respective companies) and XTP network software (developed by the Computer Networks Laboratory of the University of Virginia.) The primary and secondary storage of each node is 16 MB SIMM and 340 MB IDE type respectively.

The experiments we have performed follow two basic sequences of operation. The primary operation occurs on the transmitting side of the network communication connection. First task is to obtain video or audio analog data and to perform analog-to-digital conversion. Once completed this digitized information is then compressed using the appropriate data compression algorithm with the respective VLSI chipset (ADPCM for audio and JPEG for video) residing on the Commercial Off The Shelf (COTS) hardware. The compressed data is then formed into XTP network packets, by the application and XTP software, for transmission over the Fiber Optic network via the FDDI hardware in the node. The second set of operations is performed at the receiving node, beginning with the receipt by the Fiber Optic network and FDDI hardware in the node. These FDDI frames are processed by XTP and the resulting compressed data is delivered to the appropriate COTS hardware for decompression and the resulting data is output to either the screen in the case of video data or the speaker in the case of audio data. This completes the communication cycle.

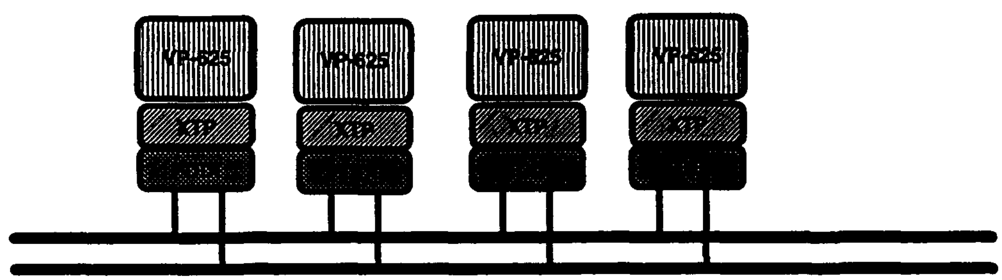

Figure 1. Schematic diagram of the Audio transmission experiment using XTP and FDDI

Voice Transmission

During the course of our audio experiments latency measurements were taken periodically. This measured latency was indicative of the time required for end to end (i.e. microphone-speaker) transmission. The results indicated a latency of approximately 25ms, which was well within the tolerable limits of perception by the human ear.

One-Way Delay	Effect of delay
>600ms	Incoherent
600ms	Barely Coherent
250ms	Annoying
100ms	Imperceptible (without network/original sample comparison)
50ms	Imperceptible (with network/original sample comparison)

Table 1: Effects of latency on human ear perception[3]

The latency tests were based upon XTP unicast mode communication link sending XTP network packets sized at 50 bytes each, and VP-625 A/D converter buffered by an array of bytes 1024 long. This schema provided a good basis for testing and analysis.

The ADPCM audio compression algorithm, which the Antex model VP-625 utilizes, compresses the sampled audio waveform to 4 bits thereby reducing the data size by over 50% compared to 10 bit PCM digitization. This compression allows for very low network bandwidth utilization. When operating in unicast mode, the average consumption of network bandwidth given a typical compressed audio packet is .5035 Mbits/sec. XTP unicast mode is a network communication utilizing 2 nodes, where one node acts as a transmitter and another node acts as a receiver. This bandwidth is increased to approximately 1.102 Mbits/sec when utilizing duplex mode communication. XTP duplex mode involves two nodes and each node acts as transmitter and receiver simultaneously. The experiments have included various aspects of XTP functionality such as option bits testing.

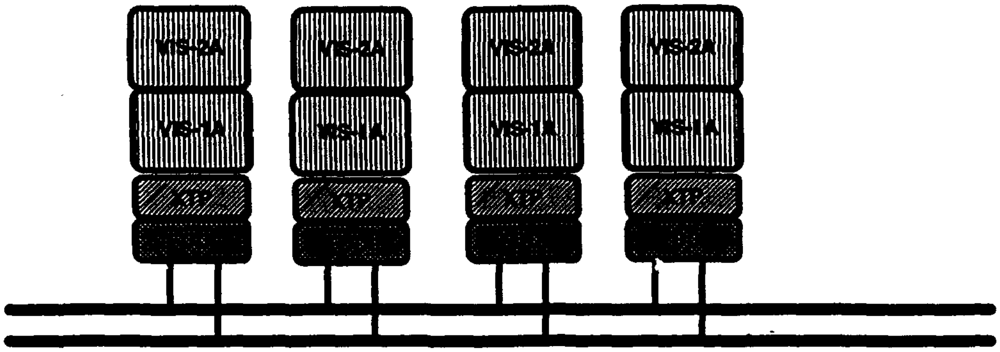

Figure 2. Schematic diagram of the Video transmission experiment using XTP and FDDI

<u>Video Transmission</u>

The realtime video we used originated from various sources such as: Cable News Network (CNN) broadcast acquired from satellite downlink; Video Camera; and Video Tape. These sources all followed the NTSC format and all were fed into the VIS-2A video frame grabber. Again, during our experiments, latency measurements were recorded periodically. This time the measured latency was representative of the time required for picture to picture (i.e. screen display to screen display) transmission. The outcome of these tests revealed a latency of approximately 50-60ms (less than 2 frames) given that our experiments were based upon utilizing NTSC standard input which is 30 fps. This small latency is very difficult to perceive, even with the source and destination display screens side by side. Table 2 represents some results of a study [3] on frame rates and their effects on human eyes. As can be seen, a jerky motion is perceived when successive frames are 67-83 ms apart. This is in excess of the latency in our experiment between a frame appearing on the source screen and the same frame appearing on the destination screen.

Frames per second	Effect on human eye
<10 fps	Frames appear disjoint
12-15 fps	Motion is jerky.
30 fps	Television quality
60-75 fps	High-motion discernible (HDTV)
90 fps	Limit of human eye perception

Table 2: Effects of frame rate on human eye perception[3]

These latency tests were also based upon XTP unicast mode communication link with XTP network packets sized at 3305 bytes each, and a video buffer of 16000 bytes. The JPEG video compression chipset utilizing

the Huffman encoding scheme provided us with 2 to 4 times data reduction thus greatly reducing the network bandwidth requirements for our realtime video communication experiments. A typical XTP unicast communication session utilized approximately 3 Mbits/sec to 6 Mbits/sec bandwidth. The XTP multicast sessions were recorded to also within the 3 Mbits/sec to 6 Mbits/sec range of network bandwidth consumption. The results of the XTP multicast bandwidth consumption is revealing in that it is within the range of the typical XTP unicast network utilization despite the fact that unicast is a 1 to 1 session and multicast is 1 to N network communication

POTENTIAL COMMERCIAL APPLICATIONS

Medical Image Transmission

Digitized medical image transmission over high speed network and using high performance network protocol will save a lot of time for doctors and laboratories to diagnose symptoms of patients. For example, after a X-ray laboratory takes the image of a patient's skull, the image can then be transmitted via the FDDI to a doctor's office and displayed in his monitor. Also it can be sent to several locations at the same time. This will save time for film processing, filing, mailing and paperwork. Both XTP and FDDI are apt for this task since medical image transmission requires high bandwidth and no error rate. Other information such as billing, documents, and patient's data can also be transmitted using the same network. Hence the amount of medical paperwork will be reduced.

On the basis of the video experiments we performed, the potential of applying our technology to the medical image transmission is good and is worth more researches.

Teleconferencing

Business organizations have been using teleconferencing for many years already. There are several advantages of using teleconferencing such as reducing travel expenses, travel time, and schedule problems. However teleconferencing has been limited by the speed of technology development. Low speed networks, low performance network protocols, and low performance hardware have created latency in voice transmission and limited the number of video frames to be transmitted.

The incorporation of XTP and FDDI into a teleconferencing network will greatly improve the performance of the teleconferencing facilities. Voice latency will be reduced and the number of video frames can be increased.

In our voice experiments, we have finished duplex, unicast, and multicast. In our video experiments, we are working on unicast and multicast. These experiments have demonstrated the feasibility of teleconferencing using XTP and FDDI. Later on, we will incorporate the audio and video experiments together in a coherent manner.

Right now our voice and video experiments are only in DOS environment using PC 486 machines. We will incorporate XTP and FDDI into RTMach environment using PC i486 machines in the near future. RTMach is a high performance realtime operating system developed by Carnegie Mellon University. After incorporation, more experiments that are not feasible in DOS such as priority experiments can be conducted in RTMach environment.

Voice and Electronic Mail in High Traffic Networks

Voice and Electronic mail have been used in business, research organizations, and government for many years. These kinds of communication provide a convenient way for users between different building and even different countries. As the number of users and the number of messages increase several times each year, the amount of network traffic also increases at a tremendous speed. This creates a need for higher performance

network and network protocols to satisfy the demanding network traffic. The use of XTP and FDDI may provide a solution. However, more research need to be done in order to incorporate existing networks to XTP and FDDI.

Remote Data Acquisition

Data Acquisition has many applications in industry. Some of these applications such as air tunnel analysis require large amount of data acquisition and transmission through computer network. This will inevitably create a bottleneck effect on the network. The use of XTP and FDDI provides a potential solution to improve the performance of the network traffic and thus facilitate the data flowing.

CONCLUSION

After performing the audio and video experiments in our testbed, the results have indicated the use of XTP and FDDI on multimedia transmission is feasible. Several potential commercial applications are described. As multimedia will become an important industry in our nation, more research in multimedia transmission is needed in order to provide an edge over our competitors.

We will cooperate with Carnegie Mellon University and University of Virginia to conduct more experiments in the future to utilize more powerful computers, operating systems, audio, and video equipment. These experiments will provide higher performance multimedia transmission, benchmarks, research data, and new technology to industries.

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